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(54) **SYSTEM AND METHOD FOR PROVIDING TRAFFIC CONGESTION RELIEF USING DYNAMIC LIGHTED ROAD LANE MARKINGS**

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(51) **Int. Cl.**
G08G 1/095 (2006.01)
G08G 1/01 (2006.01)

(52) **U.S. Cl.**
CPC ***G08G 1/0145*** (2013.01)

(58) **Field of Classification Search**
None
See application file for complete search history.

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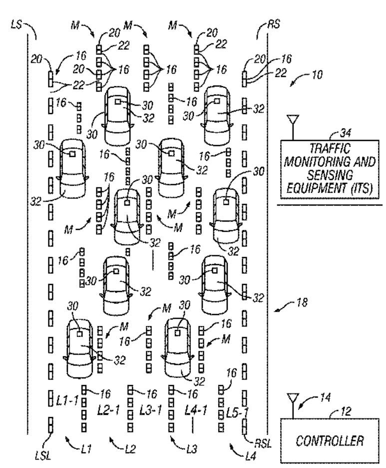
(57) **ABSTRACT**

A system and method for providing increased traffic carrying capacity of a road, such as a highway, by modifying an existing roadway from, for example, four lanes to five lanes, to create an additional travel lane. The system and method dynamically changes the width of travel lanes using, for example, embedded pavement lights, or other lighting arrangements, in lieu of traditional painted lane lines. As traffic volumes increase and speeds decrease along the road, an intelligent transport system (ITS) sends a congestion signal to the overhead lane controls and dynamic message signs (DMS) along the entire road segment of interest. The posted speed limits are changed, and the lane markings are controlled to dynamically increase the number of lanes in the road segment to five, for example, of narrower widths until traffic volumes reduce and the number of lanes can be returned to four, for example, with normal speed limits.

14 Claims, 9 Drawing Sheets



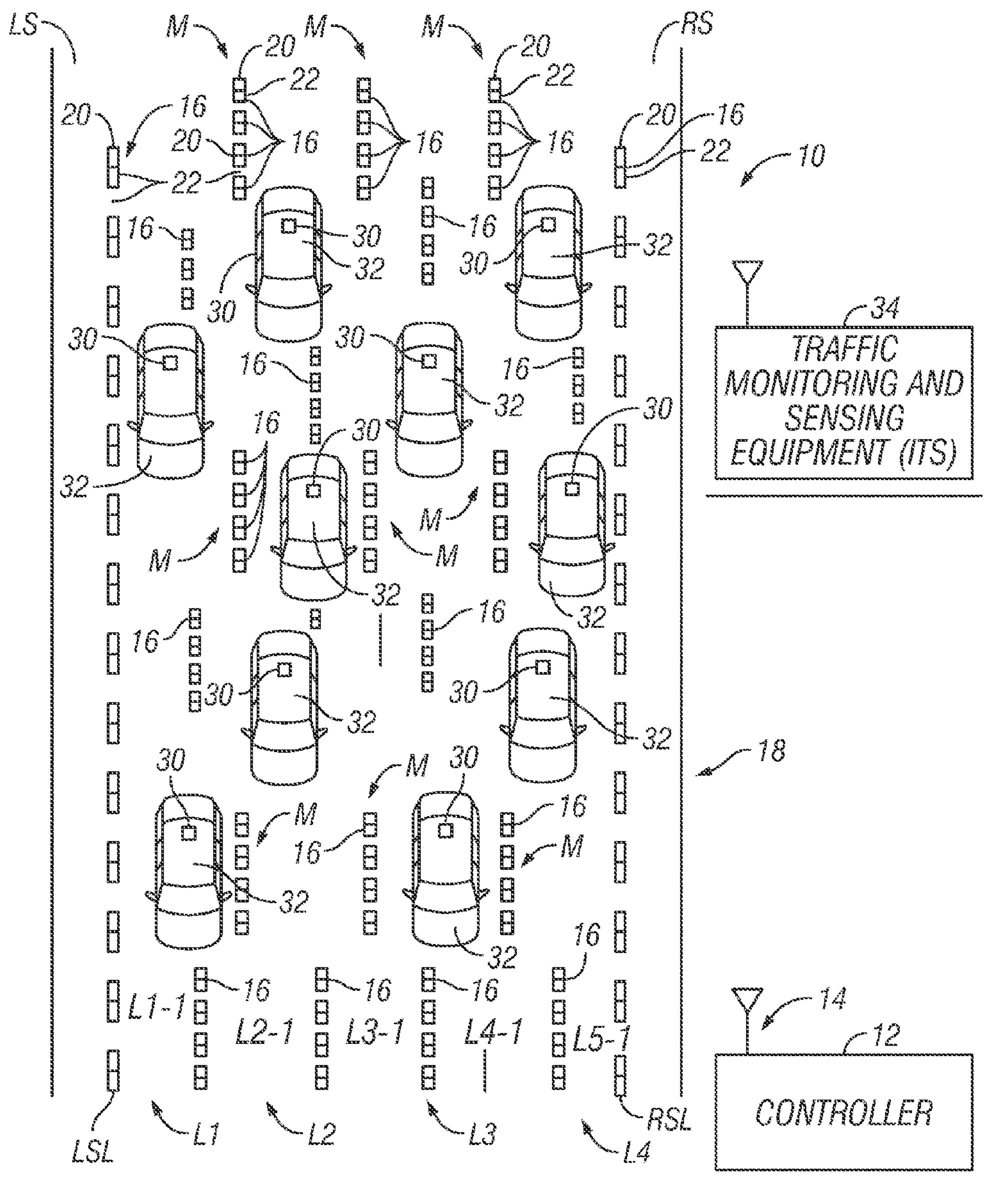

LS
RS
M
20
22
16
10
30
32
34
TRAFFIC MONITORING AND SENSING EQUIPMENT (ITS)
18
14
12
CONTROLLER
L1-1
L2-1
L3-1
L4-1
L5-1
LSL
RSL
L1
L2
L3
L4

FIG. 1

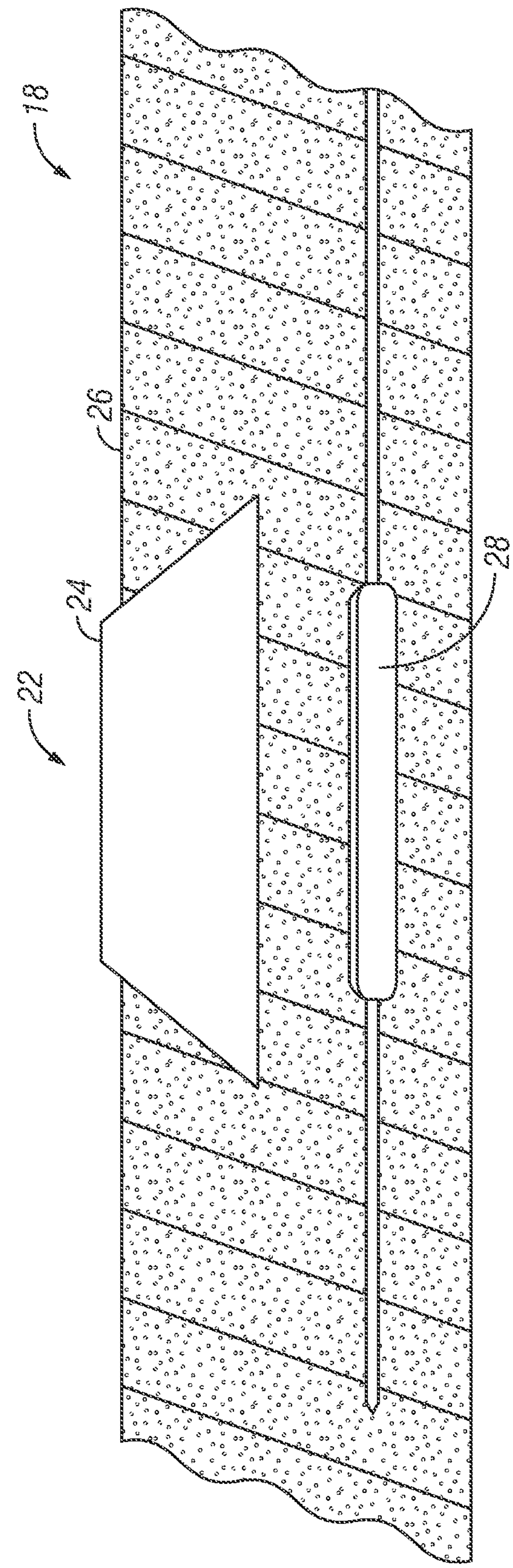


FIG. 2

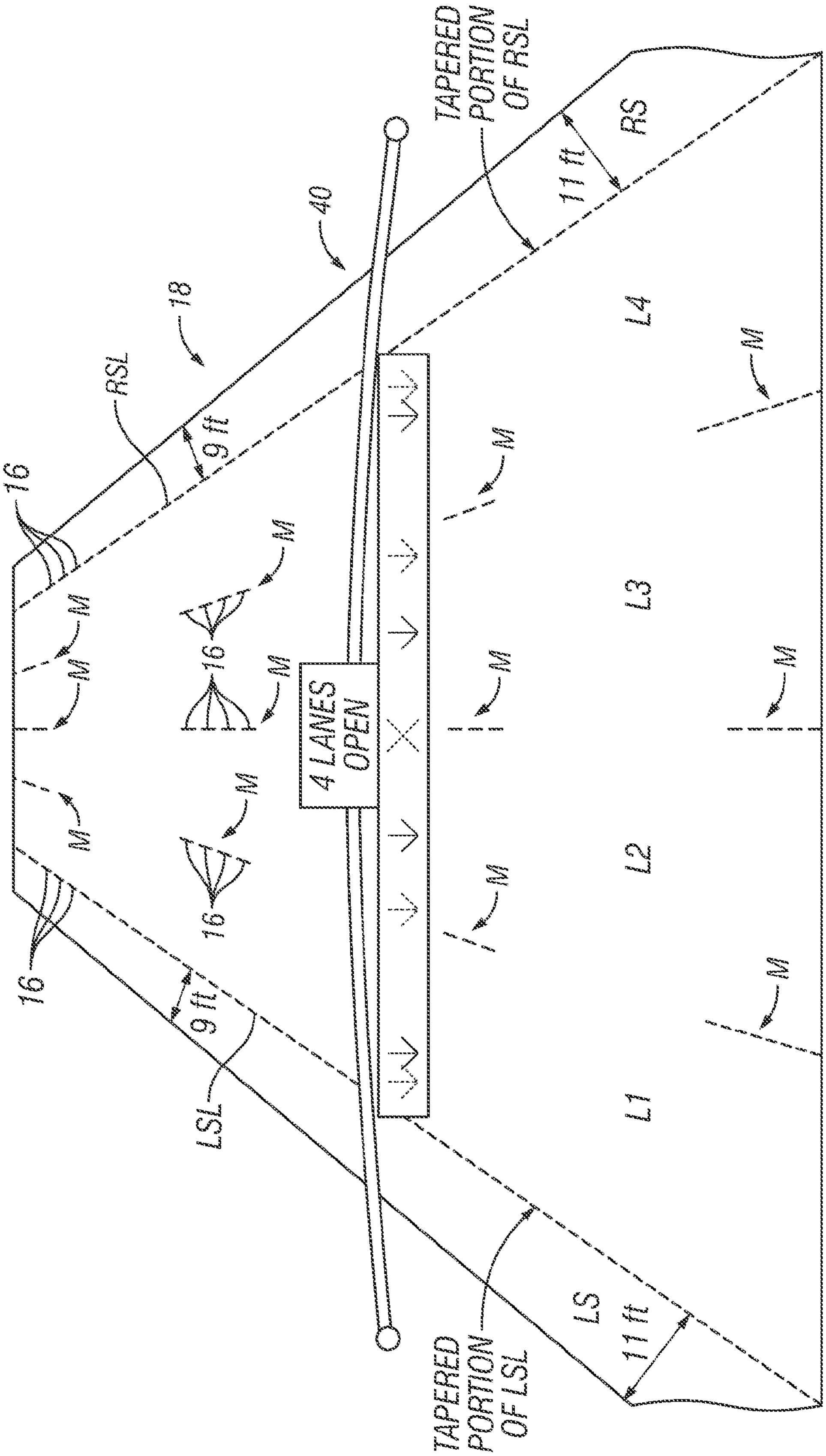

TAPERED PORTION OF RSL
40
18
RSL
9 ft
11 ft
RS
L4
L3
L2
L1
M
16
4 LANES OPEN
LSL
LS
TAPERED PORTION OF LSL

FIG. 3

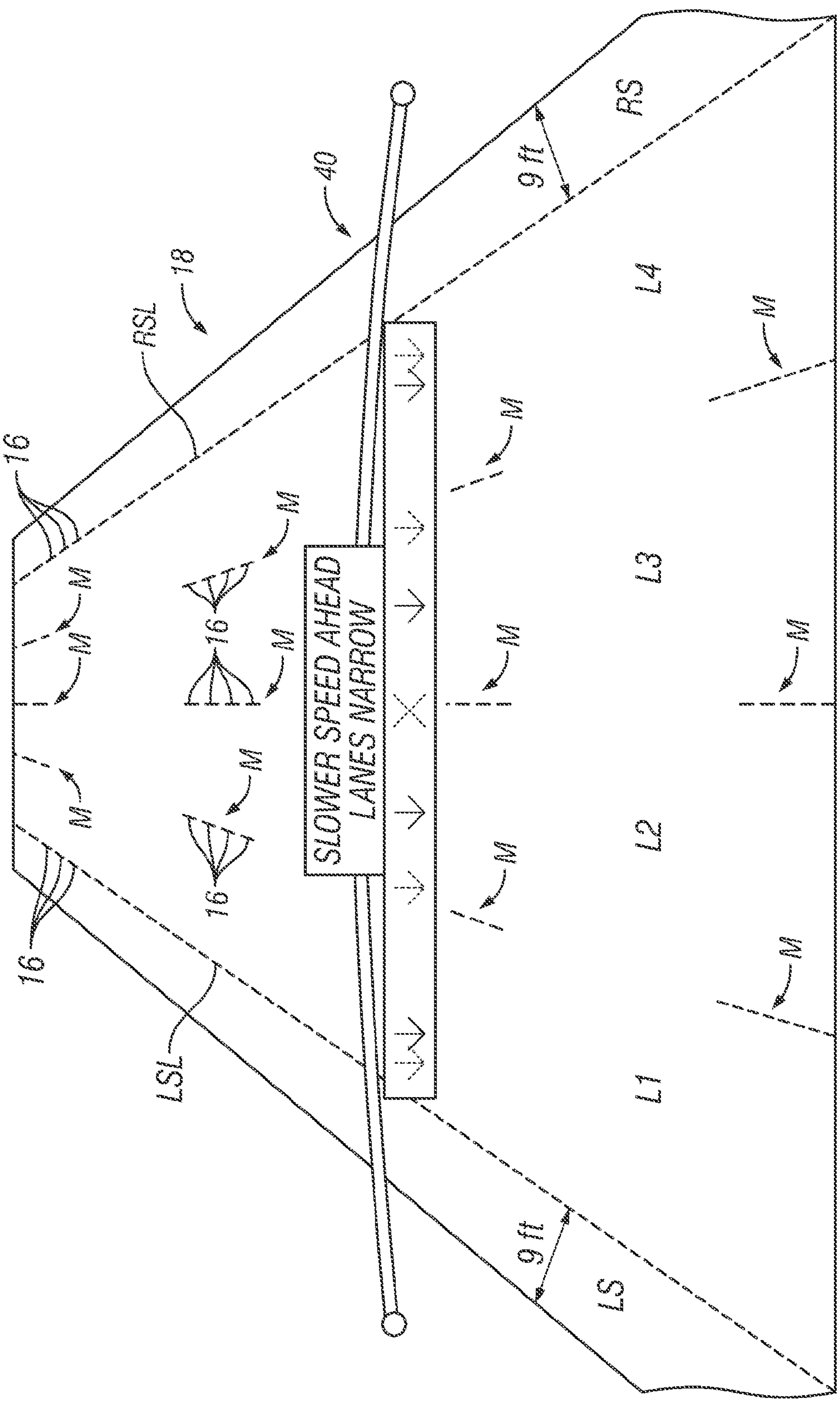

SLOWER SPEED AHEAD
LANES NARROW
40
18
RSL
LSL
RS
LS
L1
L2
L3
L4
9 ft
9 ft
16
M

FIG. 4

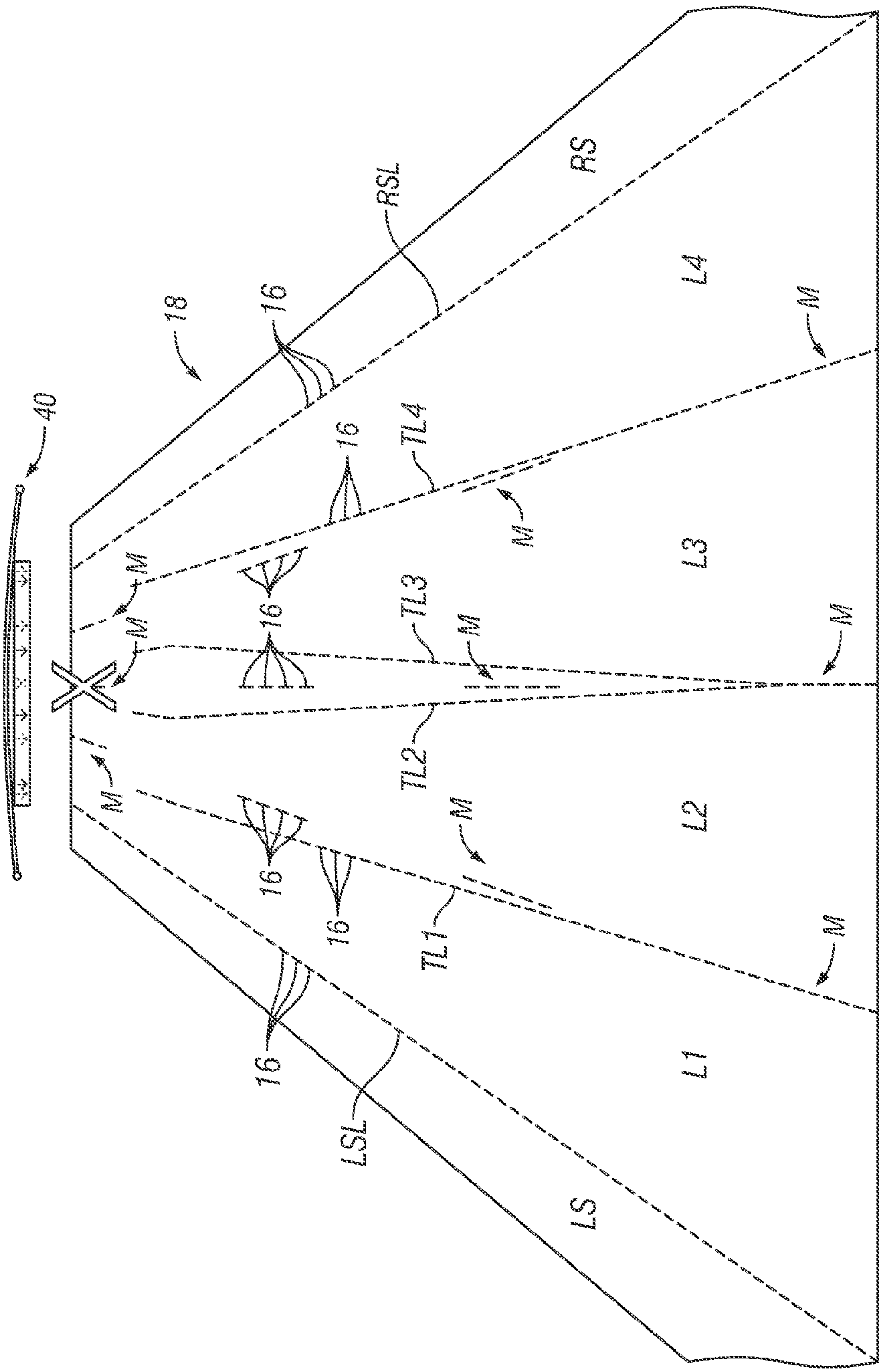


FIG. 5

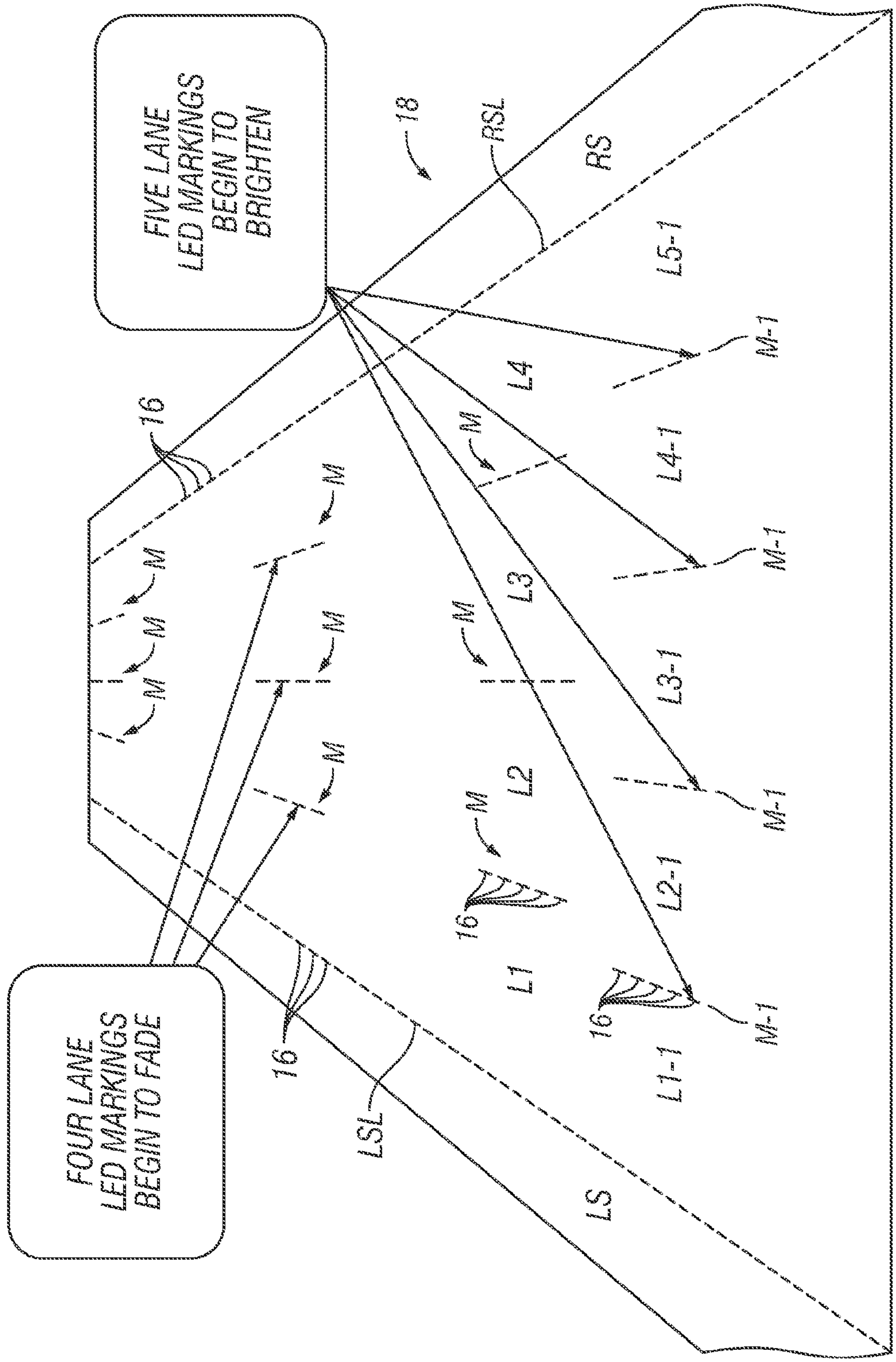

FIVE LANE LED MARKINGS BEGIN TO BRIGHTEN
FOUR LANE LED MARKINGS BEGIN TO FADE
18
RSL
RS
L5-1
L4
L4-1
L3
L3-1
L2
L2-1
L1
L1-1
LSL
LS
M
M-1
16

FIG. 6

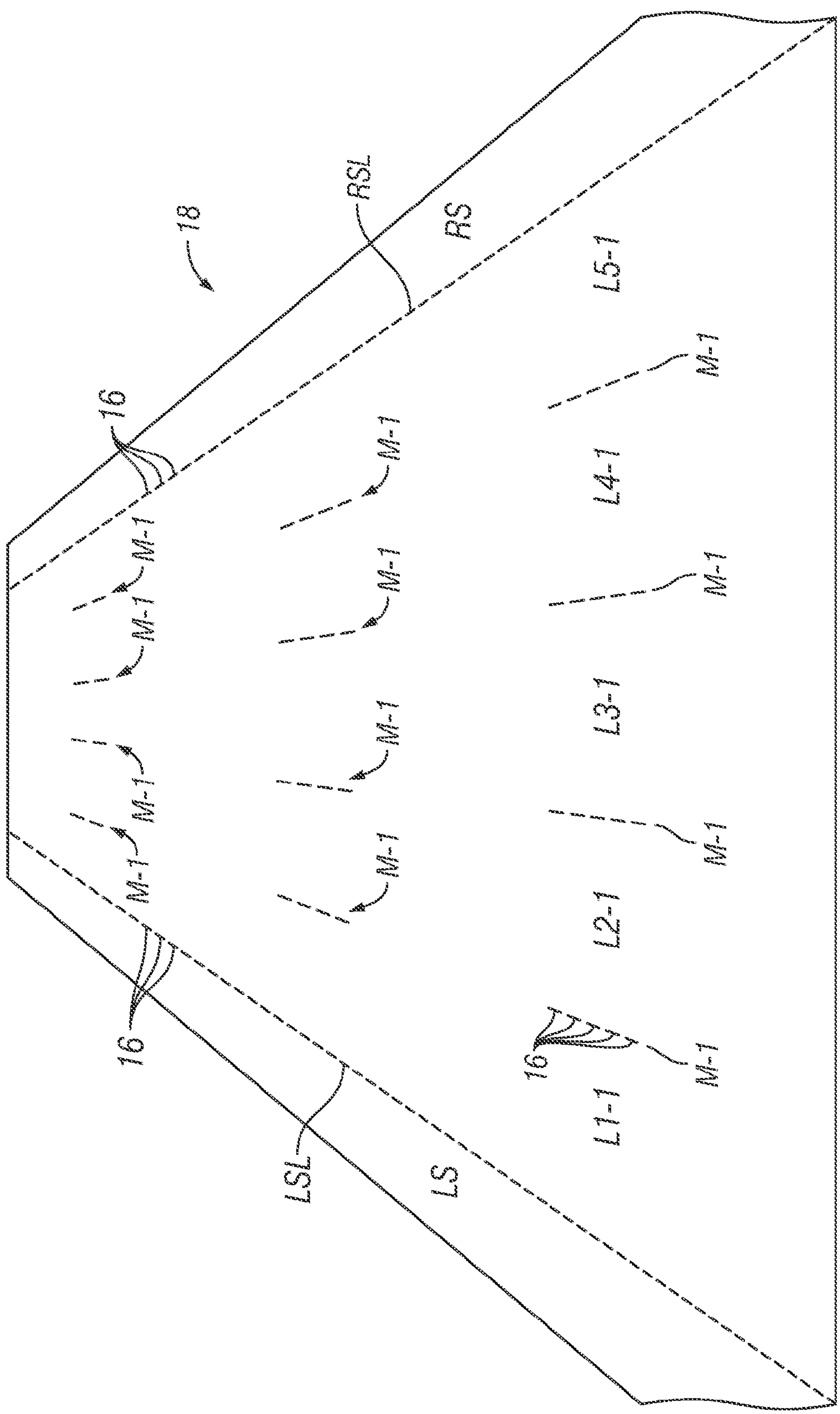


FIG. 7

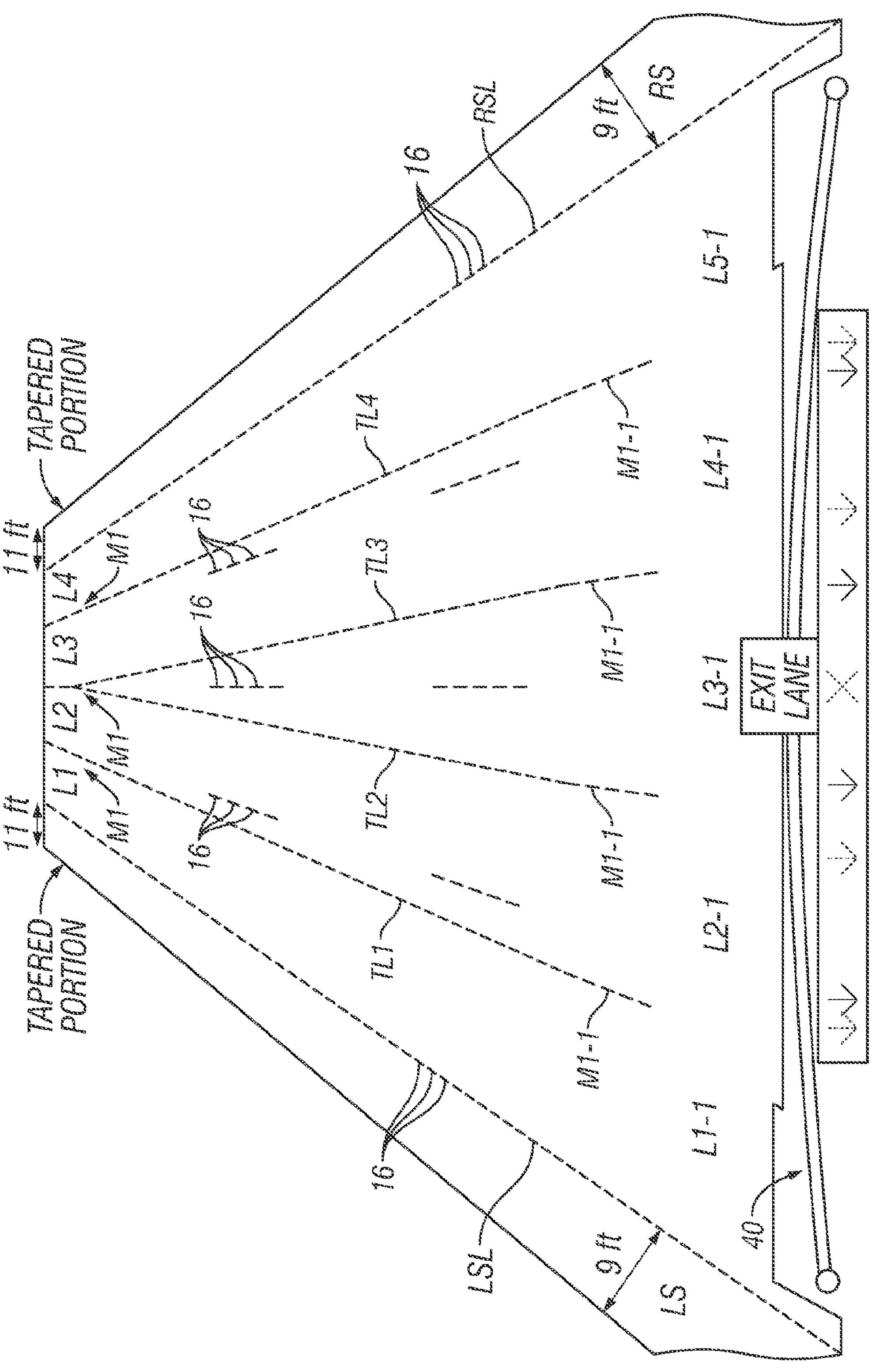

TAPERED PORTION
11 ft
L4
L3
L2
L1
M1
16
TL4
TL3
TL2
TL1
M1-1
RSL
9 ft
RS
TAPERED PORTION
11 ft
M1
M1-1
LSL
9 ft
LS
L1-1
L2-1
L3-1
L4-1
L5-1
EXIT LANE
40

FIG. 8

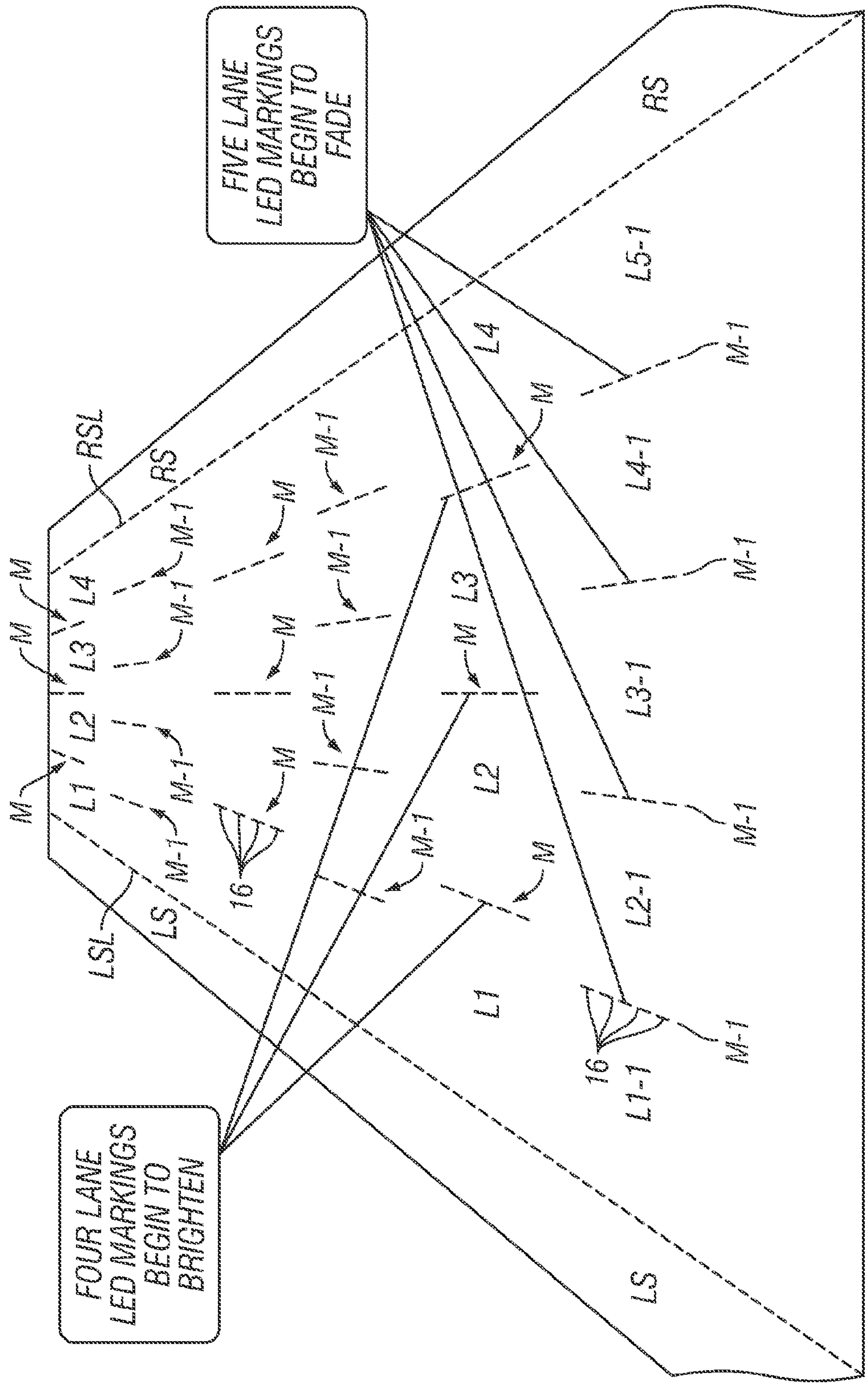

FIVE LANE LED MARKINGS BEGIN TO FADE
FOUR LANE LED MARKINGS BEGIN TO BRIGHTEN
RSL
RS
LSL
LS
L1
L2
L3
L4
L1-1
L2-1
L3-1
L4-1
L5-1
M
M-1
16

FIG. 9

SYSTEM AND METHOD FOR PROVIDING TRAFFIC CONGESTION RELIEF USING DYNAMIC LIGHTED ROAD LANE MARKINGS

CROSS-REFERENCE TO RELATED APPLICATION

This application claims priority to U.S. Provisional Patent Application No. 62/297,708, filed on Feb. 19, 2016, the entire contents of which being incorporated by reference herein.

BACKGROUND

1. Field of the Invention

The present invention generally relates to a system and method for providing traffic congestion relief. More particularly, the present invention relates to a system and method for providing traffic congestion relief by receiving data from traffic and speed sensing monitors and, based on that data, operating a lighted lane markings, such as LED in-pavement lane markings, to change the widths and number of the traffic lanes, thus maximizing the number of lanes based on congestion and speed of the vehicles and increasing road traffic carrying capacity.

2. Background Information

Federal and state highway design manuals incorporate standards which provide operational road maximization based on optimal driving conditions. For example, road geometrics are utilized based on maximum design speeds. Because these geometrics are static, the geometrics cannot change or adapt regardless of the real time operations of traffic on a road. Therefore, when the designed vehicle travel speeds are achievable, the roads function in acceptable fashion with specified design standards and geometrics. However, at other times when the designed vehicle travel speeds are not achievable due to, for example, congestion caused by over capacity of the traditional road design parameters, the road functions in a much less efficient manner. Hence, traffic jams, congestion, slower commuting travel, increased air pollution due to stop and go traffic, traffic speeds less than the designed vehicle travel speeds, and other undesirable circumstances occur.

Examples of guidelines for these type of lane configurations are set forth by the American Association of State Highway and Transportation Officials (AASHTO). For example, in urban areas where pedestrian crossings, right-of-way, or existing development place stringent controls on lane widths, the use of 3.3-m (11-ft) lanes may be appropriate. Lanes that are 3.0 m (10 ft) wide are also acceptable on low-speed facilities, and lanes 2.7 m (9 ft) wide may be appropriate on low-volume roads in rural and residential areas. Further information is available in the NCHRP Report 362, Roadway Widths for Low-Traffic Volume Roads (45). In some instances, on multilane facilities in urban areas, narrower inside lanes may be utilized to permit wider outside lanes for bicycle use.

Thus, traditional roads either serve a single purpose of a higher speed highways or at lower speed urban arterial, but not both. Typically, neither type of road can effectively adapt to changes in traffic volume and so on, which can often change several times during a typical day. Roadways in urban areas are designed with different standards based on the objectives of the proposed highway operations, and transportation public agencies often stipulate specified design standards of the proposed road segments. Once constructed, either the highway or the arterial will incorporate geometrics to address the proposed operational standards, thereby forgoing any geometric flexibility to adapt the road to changing needs, such as changes in traffic volume and so on.

With conventional road geometrics, it is very common for roadway operations to change during certain times of the day due to non-controllable events such as high commuter volumes experienced during peak rush hours, inclement weather conditions, or highway incidents. During these times, optimization of traffic carrying capacity is generally not achievable on conventional roads, mainly because road geometrics remain static based on the designed speed standards. For example, highway design speeds in the 50 to 60 mph range commonly mandate lane widths of 12 feet. However, urban arterial roads with higher volumes of traffic can and should operate with narrower lanes, such as 10 feet wide lanes. The narrower lanes are permissible for vehicles to operate safely and efficiently at speeds of 40 miles or less. Also, the 10 feet wide lanes may actually encourage maintaining the lower speeds in urban congestion areas, as is apparent based on studies throughout the country. Nevertheless, because the road geometrics on these conventional roads are static, the geometries remain unchanged even if different geometries would be appropriate to accommodate different traffic conditions.

Accordingly, in view of the above shortcomings, a need exists for an improved system and method for providing traffic congestion relief.

SUMMARY

One aspect of the present invention provides a system and method for providing increased traffic carrying capacity of a road, such as a highway. The system and method operates to reduce traffic congestion and increase driving safety by modifying an existing roadway from, for example, four lanes to five lanes to create an additional travel lane. In particular, the system and method dynamically changes the widths and number of travel lanes using dynamic indicators, such as LED embedded pavement lights in the road surface or other types of lighting arrangements, in lieu of traditional painted lane lines. The system and method utilize, for example, functionality of an intelligent transportation system (ITS). As traffic volumes increase and speeds decrease along the road, the ITS sends a signal, such as a wireless signal, to the overhead lane controls and dynamic message signs (DMS) along the entire segment of the road of interest. The system and method send signals to change the posted speed limits and the LED in-pavement lane markings to dynamically increase the number of lanes in the road segment such that the road segment has more lanes (e.g., 5 lanes instead of 4) of narrower widths (e.g., approximately 10 feet wide each instead of the standard 12 feet wide lanes). The system and method maintain the increased number of lanes until traffic volumes reduce and vehicle are capable of operating using the original number of lanes of standard lane width dimensions. The system and method thus controls the lane markings in the road segment to transition back to the original four-lane configuration with normal speed limits.

These and other objects, features, aspects and advantages of the present invention will become apparent to those skilled in the art from the following detailed description, which, taken in conjunction with the annexed drawings, discloses a preferred embodiment of the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

Referring now to the attached drawings which form a part of this original disclosure:

FIG. **1** is a block diagram illustrating an example of a system for providing traffic congestion relief using dynamic lighted road lane markings according to a disclosed embodiment;

FIG. **2** is a cross-sectional view of a road segment illustrating an example of a lighting device, such as an LED device, that is embedded in the road segment and operates as a dynamic lighted road lane marking employed in the system shown in FIG. **1**;

FIG. **3** is a diagrammatic view illustrating an example of a road segment being controlled by the system shown in FIG. **1** to illuminate four road lanes of the road segment under normal traffic conditions;

FIG. **4** is a diagrammatic view illustrating an example of a road segment being controlled by the system shown in FIG. **1** to illuminate four road lanes of the road segment in advance of a congested area;

FIG. **5** is a diagrammatic view illustrating an example of a transition between four lanes to five lanes in the road segment;

FIG. **6** is a diagrammatic view further illustrating an example of a transition between four lanes to five lanes in the road segment;

FIG. **7** is a diagrammatic view illustrating an example of a road segment being controlled by the system shown in FIG. **1** to illuminate five road lanes of the road segment under congested traffic conditions;

FIG. **8** is a diagrammatic view illustrating an example of a transition between five lanes back to four lanes in the road segment; and

FIG. **9** is a diagrammatic view illustrating an example of a transition between five lanes to four lanes in the road segment.

DETAILED DESCRIPTION OF EMBODIMENTS

Selected embodiments will now be explained with reference to the drawings. It will be apparent to those skilled in the art from this disclosure that the following descriptions of the disclosed embodiments are provided for illustration only and not for the purpose of limiting the invention as defined by the appended claims and their equivalents.

FIG. **1** illustrates an example of a system and method for providing traffic congestion relief **10** (known as "SmartRoad") according to a disclosed embodiment. As shown, the system **10** includes one or more controllers **12**. Each controller **12** includes at least one communication device **14**, such as a wireless communication device or wired communication device, for communicating information to and from external sources. For example, the communication device **14** enables the controller **12** to communicate with dynamic indicators **16** associated with a road segment **18**, such as a portion of a highway or any type of road that permits vehicular traffic. As discussed herein, the dynamic indicators **16** are grouped or configured to represent lane makers (e.g., dashes) M as would typically be represented by painted markers on a conventional road segment. As with standard painted lane markers, each lane marker M has a length of 10 feet, and the lane markers M are separated from each other by 30 feet. Naturally, the length of each lane marker M and the separation between adjacent lane markers M can be any suitable value as understood in the art. Also, the dynamic indicators **16** are positioned to represent the left shoulder line LSL and right shoulder line RSL as would also typically be represented by paint on a conventional road segment. Each dynamic indicator **16** in this example can include a communication device **20** for communicating with, for example, the communication device **12** of the controller **10** or any other external communication devices wirelessly or in a wired manner as understood in the art. Each communication device **20** can include a processor or type of controller for controlling operation of the dynamic indicator **16** as discussed herein and as understood in the art. Also, in certain geometric situations including sharp curves, dynamic indicators **16** placed close to each other, such as 3 feet apart, can be utilized as appropriate.

The communication device **20** can also communicate with other communication devices **20** in other dynamic indicators **16** such that the dynamic indicators **16** can communicate with each other. Each dynamic indicator **16** in this example further includes an indicator device **22**. An indictor device **22** can be a lighting device, such as LED lights, fiber optic strips, light pipes, shifting colored plates, and so on, that is, for example, embedded into the surface of the road segment **18**, or fixed to or associated with the road **18** in any suitable manner as discussed herein and understood in the art.

The indicator device **22** also can be any of the other type of active or passive indicator devices discussed herein, or a combination of such indicator devices. For instance, an indicator device **22** can be a surface of a dynamic indicator **16** that is illuminated by a lighting device, such as a laser, that is positioned above the road segment **18** or at any other appropriate location. An indicator device **22** can be an imprinted or painted surface that is activated or illuminated by a lighting device or energy emitting device positioned above the road segment **18** or at any other appropriate location. Also, in a smart vehicle technology application, an indicator device **22** can include an interface that provides an invisible track along which a smart vehicle (e.g., a "driverless vehicle") is controlled to travel, thus creating a virtual lane for the vehicle. Naturally, any indicator device **22** can include a combination of these types of technologies as desired. Furthermore, each dynamic indicator **16** can illuminate a certain color. For example, the dynamic indicators **16** positioned as lane markers M can illuminate white, or a different color such as yellow or amber. Likewise, dynamic indicators **16** positioned to represent the left shoulder line LSL and right shoulder line RSL can illuminate white, or a different color such as yellow or amber. In this example, the left shoulder lane LSL illuminates in yellow or amber, in particular. Other dynamic indicators **16** positioned as the taper lines discussed below can illuminate white, or any other suitable color such as yellow or amber.

As can be appreciated from the description herein, the dynamic indicators **16** can include embedded durable LED lights, such as the LED light **24** shown in FIG. **2**, as the indicator devices **22**. Each LED light **24** in this example is embedded in the surface **26** of the road segment **18**. As discussed herein, these LED lights **24** replace the traditional painted white lines or any other types of traditional fixed or movable types of barriers, such as cones, pylons and so on. The LED lights **24** are very durable, self-cleaning, and have been approved for use throughout the world for traffic related applications.

The dynamic indicators **16**, such as those including the LED lights **24**, in this example can also include illumination controls which will automatically adjust based on the time of the day and during inclement weather conditions. The LED in embedded pavement lights can in this example be clearly visible during bright sunlight, but will not be overwhelming for night time driving. The brightness will be controlled automatically through the technology operational sensor system of the system **10** as understood in the art.

The LED lights **24** are embedded slightly above the elevation of the surface **26** of the pavement of the road section **18** to allow for normal plowing operations. The LED lights **24** have a design life of over 10 years, therefore maintenance is minimal. A non-connected energy source, such as an inductive power transfer source **28**, can be used to power the LED lights **24**. Thus, there need not be direct wire connections to the LED lights **24**, which are typically the cause of maintenance issues due to corrosion. However, the dynamic indicators **16**, such as those including the LEDs lights **24** as the indicator devices **22**, can be powered in any other suitable manner, including wired power, solar power, and so on. Moreover, since the LED lights **24** can be one-way directional, the emitted light will not interfere with opposing traffic motorist. The in-pavement LED lights **24** could be installed using a coring drill device or any other suitable equipment as understood in the art. Also, power cabling for operation of the in-pavement LED markings can be saw cut into the pavement and sealed with high-strength epoxy, or in any other suitable manner, followed up with an asphalt topping coat or other pavement type to complete the installation.

As further shown in FIG. **1**, the communication device **14** associated with the controller **12** also enables the controller **12** to communicate with any suitable type of communication device **30** on vehicles **32**, to exchange information between the controller **12** and the vehicles **32**. Furthermore, the communication devices **20** of the dynamic indicators **16** can communicate with the communication devices **30** on the vehicles **32** as understood in the art. For instance, the controller **12** and the dynamic indicators **16** can communicate with GPS devices, mapping devices and other devices on the vehicles **32** so that the GPS and mapping devices can display a representation of the virtual lanes created by the dynamic indicators **16** along the road segment **18**. Also, by linking the controller **12** to databases such as weather radar, the roadway can make adjustments to the road geometrics in a manner described below during inclement weather thereby slowing speeds on the road, adding an additional travel lane and minimizing the potential for accidents. Thus, the system **10** could follow a storm and make real time adjustments to the roadway in order to increase capacity, but also slow down speeds in a manner described below. The system **10** can also control the dynamic indicators **16** as described below to change the road configuration due to special conditions or events, even in cases of national emergency.

As discussed in more detail below, the controller **12** includes hardware and software for controlling the system **10**, and can also allow a form manual control of at least some of the features of the system **10**. The controller **12** preferably includes a microcomputer with a control program that controls components of the system **10**, such as the communication device **14**, dynamic indicators **16** and other components as discussed herein. The controller **12** includes other conventional components such as an input interface circuit, an output interface circuit, and storage devices such as a ROM (Read Only Memory) device and a RAM (Random Access Memory) device. It will be apparent to those skilled in the art from this disclosure that the precise structure and algorithms for the controller **12** can be any combination of hardware and software that will carry out the functions of the present invention. Also, a processor of a communication device **20** of each a dynamic indicator **16** can include similar features for controlling the communication device **20** and operating the dynamic indicator **16**. Furthermore, the controller **12** can communicate with the other components of the system **10** discussed herein in any suitable manner as understood in the art. In addition, the controller **12** can employ software monitoring to detect any malfunctions of, for example, the in-pavement LED lights **24**, the overhead gantry signs **40** and so on. Hence, monitoring and maintenance operations can be constantly monitored, and maintenance messages can be sent automatically to the road operations center by the controller **12**. The controller **12** can also provide real-time information on energy usage due associated with the in-pavement LED lights **24** and so on.

That is, the controller **12** communicates with traffic monitoring and sensing equipment **34** as known in the art, such as an intelligent transportation system (ITS) as discussed above, which detects vehicle speeds on the road segment **18**, such as slower vehicle speeds. Each unit of the traffic and monitoring sensing equipment **34** can be positioned at certain distances along the road segment **18**, such as every half mile or at any other suitable distances. The traffic monitoring and sensing equipment **34** typically operates 24 hours a day, 7 days a week. The traffic monitoring and sensing equipment **34** also can include equipment as known in the art for monitoring, for example, weather conditions or other conditions affecting the road segment **18**. Naturally, such weather monitoring equipment and other monitoring equipment can be disposed at any suitable locations with respect to the road segment **18**, and can communicate directly with the controller **12**, the dynamic indicators **16**, the vehicles **32** and so on. Thus, the traffic monitoring and sensing equipment **34** includes a communication device **36** that communicates information pertaining to such vehicle speeds to the controller **12** wirelessly or in a wired manner as understood in the art. The traffic monitoring and sensing equipment **34** is also capable of communicating via the communication device with the dynamic indicators **16**, the vehicles **32** and any other external devices as understood in the art and described herein. For instance, the traffic monitoring and sensing equipment **34** can communicate with overhead gantry signage signal **40** as discussed herein. The overhead gantry signs **40** can be programmable and have, for example, a life cycle of 10 years or more.

Examples of functionality of the system **10** will now be described. Although the examples below mainly discuss the use of LED lights **24** as the types of indicator devices **22**, any configuration of the indicator devices **22** as discussed herein (e.g., laser activated, smart vehicle technology and so on) can be used in the examples described herein. The system **10** thus allows for road segments **18** to change and adapt to different traffic volume needs of a road as necessary for purposes of optimizing traffic capacity. The road segment **18** can change its geometrics as needed in real time to provide duel service of a higher speed highway versus an urban arterial. Thus, the system **10** is operable to increase, in a safe and environmentally sensitive approach, traffic capacity in traditional roads. Also, in a smart vehicle technology application, the dynamic indicators **16** provide an invisible track along which a smart vehicle (e.g., a "driverless vehicle") is controlled to travel.

FIGS. **3** through **8** illustrate a road segment **18** employing features of the system **10** as discussed above. The road segment **18** can be, for example, a portion of a highway that commonly experiences congestion during morning and evening commuting times. For instance, a road segment **18** can be a segment of I-270 near Washington, D.C. that commonly experiences congestion during morning and evening commuting times. The road segment **18** can be several miles long, such as 10 miles or any suitable length as is necessary for the road at issue. Also, prior to and after the road segment **18**, the road markers and shoulder lines are represented by conventional painted lines.

As discussed above, the controller **12** receives information from the traffic monitoring and sensing equipment **34** (e.g., the ITS) pertaining to monitored vehicle speeds, monitored traffic volume and so on. As indicated in FIG. **3**, during normal vehicle traffic conditions in the road segment **18**, the controller **12** controls the dynamic indicators **16** to illuminate markers M to represent four lanes L**1**, L**2**, L**3** and L**4** as would be represented on a typical four lane highway by painted markings. The dynamic indicators **16** begin where the conventional painted lines end along the road at the beginning of the road segment **18**, and extend throughout the entire road segment **18** as will now be described.

For example, each of the four lanes L**1** through L**4** of a standard highway having painted markers has a standard width of 12 feet, and each of the left and right shoulders LS and RS of a standard highway having standard painted shoulder lines have a standard width of 11 feet. In this exemplary configuration, the beginning of the road segment **18** begins at the point on the road where the painted shoulder lines and the painted markers end. Thus, at the beginning of the road segment **18**, the dynamic indicators **16** are positioned to represent the lane markers M (e.g., white dashes), the left shoulder line LSL and the right shoulder line RSL. As with standard painted lane markers, each lane marker (dash) M has a length of 10 feet, and the lane markers (dashes) Ms are separated from each other by 30 feet intervals. Also, the dynamic indicators **16** identify the left shoulder line LSL of the left shoulder LS and the right shoulder line RSL of the right shoulder RS of the road segment **18**.

Furthermore, at the beginning of the road segment **18**, the dynamic indicators **16** are positioned along the portion of the road segment to provide a 140 feet long taper of the left shoulder line LSL and the right shoulder line RSL to decrease the width of the left shoulder LS and the width of the right shoulder RS from 11 feet to 9 feet. This causes the width of the leftmost lane L**1** and the width of the rightmost lane L**4** to increase to 14 feet each. Thus, during normal non-peak traffic times, the dynamic indicators **16** making up the left shoulder line LSL, the right shoulder line RSL and the markers M outline the leftmost lane L**1** having a width of 14 feet wide, the two middle lanes L**2** and L**3** each having a width of 12 feet, and the rightmost lane L**4** having a width of 14 feet as shown in FIG. **3**. This arrangement of the wider leftmost lane L**1** and rightmost lane R**1** decreases the likelihood that vehicles **32** transitioning from the four lane configuration to the five lane configuration discussed below will overrun dynamic indicators **16** making up the markers M between the lanes. Naturally, the tapered portion of the road segment **18** need not extend for 140 feet along a portion of the road segment **18**, but can be any suitable length. Also, the tapered portion of the road segment **18** need not begin exactly where the conventional painted lines on the road segment **18** end, but rather, the dynamic indicators **16** may be positioned for a short distance after the painted lines end without tapering the left shoulder line LSL and the right shoulder line RSL, and then the tapered portions of the left shoulder line LSL and the right shoulder line RSL can begin. Moreover, the widths of the left shoulder LS and right shoulder RS can be decreased to any suitable value in a manner consistent with the description herein.

The ITS or the controller **12** also controls the overhead gantry sign **40** to indicate that all four lanes L**1** through L**4** are open and speed is normal (e.g., 65 mph). Therefore, while the controller **12** receives information from the traffic monitoring and sensing equipment **34** indicating that travel conditions are normal (e.g., no congestion conditions exist), the controller **12** continues to control the dynamic indicators **16** to represent the four lanes L**1** through L**4**, the left shoulder line LSL and the right shoulder line RSL as shown in FIG. **3** for the entire road segment **18**. In addition, the controller **12**, the ITS or both can wirelessly communicate information pertaining to the road lane configuration to the communication devices **30** on the vehicles **32** so that the vehicles **32** can, for example, provide this information to their drivers via visual and/or audio representations, such as on a GPS map display, via audible warnings and so on.

When the traffic monitoring and sensing equipment **34** determines that, for example, the traffic pattern on the road segment **18** indicates that there is congestion in the road segment **18**, the controller **12** receives information from the traffic monitoring and sensing equipment **34** indicating that a congestion condition is being detected. Thus, as shown in FIG. **4**, the ITS or the controller **12** can control the overhead gantry sign **40** to indicate to motorist that there is congestion ahead and that the lane configuration will be changing. The initial signage information can appear on overhead gantry signs **40** upstream of the congestion area of the road segment **18** by approximately 2 miles, for example, or any suitable distance. As with a conventional highway, overhead gantry signs **40** are positioned along the road segment **18** at certain distances, such as every 1,100 feet apart or at any suitable spacing.

As the motorist continues to travels closer to the congestion area, the overhead gantry sign **40** along the road segment **18** at a location closer to the congested area will inform the motorist to follow the illuminated dynamic indicators **16**. The overhead gantry signs **40** also provide an indication to inform the driver that the lanes on the road segment **18** will narrow and speeds will decrease (e.g., to 45 mph or any appropriate speed as understood in the art). This provides the motorist adequate time to adjust driving patterns before entering the congested area. Such information, along with the increased awareness of the different lane patterns provided by the dynamic indicators **16**, improve operating safety of the vehicles **32** in the congested area along the road segment **18**.

As shown in FIG. **5**, the dynamic indicators **16** are positioned along a portion of the road segment **18** to provide a taper which directs drivers of the vehicles **32** toward the lanes of the new lane pattern. In this example, dynamic indicators **16** are positioned to create taper lines TL**1**, TL**2**, TL**3** and TL**4** which provide an illuminated path for the drivers of the vehicles **32** toward the lanes of the five lane road pattern which is shown in FIG. **6**. The taper lines TL**1** through TL**4** can illuminate in any suitable color, such as white, yellow or amber. In this example, the middle taper lines TL**2** and TL**3**, in particular, illuminate in yellow or amber. Also in this example, taper lines TL**1**, TL**2**, TL**3** and TL**4** begin at the end of the 140 feet long tapered section of the left shoulder line LSL and the right shoulder line RSL and extend for 500 feet along the road segment **18** to transition the four lanes L**1** through L**4** into five lanes L**1-1** through L**1-5**.

As further shown in FIG. **6**, during, shortly after and/or shortly before the portion of the road segment **18** at which the taper lines TL**1**, TL**2**, TL**3** and TL**4** are present, the controller **12** can control the dynamic indicators **16** representing the lane markers M for the four lanes to fade in illumination while the controller controls the dynamic indicators representing the lane markers M-**1** for the five lanes to increase in intensity. Naturally, the taper lines TL**1**, TL**2**, TL**3** and TL**4** need not extend for 500 feet along the road segment **18**, but can extend for any suitable length in a manner consistent with the description herein. Also, the taper lines TL**1**, TL**2**, TL**3** and TL**4** need not begin at the end of the 140 feet long tapered segment, but can begin at a location within the 140 feet long tapered segment, or after a suitable distance from the end of the 140 feet segment. In this example, the dynamic indicators **16** are positioned to illuminate a five lane pattern with the leftmost lane L**1-1** having a width of 10.5 feet, the left of center lane L**2-1** having a width of 10 feet, the center lane L**3-1** having a width of 11 feet, the right of center lane L**4-1** having a width of 10 feet, and the rightmost lane L**5-1** having a width of 10.5 feet. The left shoulder LS and right shoulder RS each will still have a width of 9 feet which does not change throughout the five lane portion of the road segment **18**. Also, during the 500 feet long transition portion, an overhead gantry sign **40** can display a signal, such as a flashing or solid red "X," above the center lane L**3-1** to indicate to drivers of the vehicles **32** that the center lane L**3-1** should not yet be used. Thus, after the after the 500 feet long transition portion of the road segment **18**, another overhead gantry sign **40** can display a signal, such as a green arrow, indicating that vehicles **32** can begin to use the center lane L**3-1** (the 5^{th} lane) that is 11 feet wide.

The dynamic indicators **16** representing the five lane configuration extend from a location beginning within the 500 feet long transition portion at the beginning of the road segment **18**, and along the entire road segment **18** to a location ending within the 500 feet long transition portion at the end of the road segment **18** as discussed below. Accordingly, the addition of the center lane L**3-1** increases traffic capacity by 25 percent over the four lane configuration, and thus relieves traffic congestion without expanding the highway footprint. Moreover, by occupying a slight portion of the left shoulder LS and the right shoulder RS (e.g., 2 feet of each shoulder), the five lane configuration section easily fits within the existing pavement areas of roads such highways. The narrower lanes are also more optimal for the slower speeds and discourage higher speeds during these times of congestion, near an accident site, or during inclement weather. Thus, the narrower lanes L**1-1** through L**5-1** also provide speed "calming" to encourage safer operation due to congestion or other incidents, or adverse weather conditions. Also, the system **10** need not be limited changing between four and five lanes, but can be configured to change between any suitable number of lanes. For instance, the system **10** can be configured to change between three lanes and four lanes, five lanes and six lanes, and so on, depending on the number of lanes on the paved road. Also, if the width of the paved road changes in the road segment **18**, the system **10** can employ an additional transition portion and, if necessary or desirable, an additional tapered portion, to further change the number of lanes within the road segment. For example, if the width of the paved road changes in the road segment **18** to be wide enough to accommodate five lanes, the system **10** can employ an additional transition portion and, if necessary or desirable, an additional tapered portion, of the types shown in FIGS. **3** through **5**, with dynamic indicators **16** arranged to enable a transition from five to six lanes.

As shown in FIG. **7**, the controller **12** can continue to control the dynamic indicators **16** representing the lane markers M-**1** to represent the five lanes L**1-1** through L**5-1**. At a position near the end of the road segment **18**, the controller **12** can control the dynamic indicators **16** to transition back to the original four lane configuration with four lanes L**1** through L**4**. For instance, as shown in FIG. **8**, during a 500 feet transition portion near the end of the road segment **18**, the controller **12** can control the dynamic indicators **16** to illuminate the lane markers M, the left shoulder line LSL and the right shoulder line RSL to represent the width of the left shoulder LS and the width of the right shoulder RS at 9 feet each, with the leftmost lane L**1** having a width of 14 feet wide, the two middle lanes L**2** and L**3** each having a width of 12 feet, and the rightmost lane L**4** having a width of 14 feet.

After this 500 feet transition portion, another 140 feet taper portion exists in which the dynamic indicators **16** representing the left shoulder line LSL and the right shoulder line RSL are configured to increase the width of the left shoulder LS and the width of the right shoulder RS to 11 feet each where the painted shoulder lines and painted lane markers begin again on the road. Naturally, this 140 taper portion can begin at a location within the 500 feet transition portion, or at a position shortly after the 500 feet transition portion. Also, the lengths of the taper portion and the transition portion need not be 140 feet and 500 feet, respectively, but can be any suitable length in a manner consistent with the description herein. Furthermore, the transition portion can include dynamic indicators **16** which are positioned to represent taper lines TL**1**, TL**2**, TL**3** and TL**4** that taper in a direction opposite to that described above to transition from five lanes L**1-1** through L**5-1** to four lanes L**1** through L**4**. In this example, the middle taper lines TL**2** and TL**3**, in particular, illuminate in yellow or amber, but the taper lines TL**1** through TL**4** can illuminate in any suitable color such as white, yellow or amber. Also, during the 500 feet long transition portion, an overhead gantry sign **40** can display a signal, such as a flashing or solid red "X," above the center lane L**3-1** to indicate to drivers of the vehicles **32** that the center lane L**3-1** should no longer be used. Furthermore, if the width of the paved road in the road segment **18** accommodates additional lanes (e.g., six lanes) as discussed above, the system **10** can employ an additional transition portion and, if necessary or desirable, an additional tapered portion, to enable a transition from six lanes to five lanes as the width of the paved road decreases, before decreasing from five lanes to four lanes.

In addition, as shown in FIG. **9**, the controller **12** can control the dynamic indicators **16** representing the lane markers M-**1** for the five lanes to fade in illumination while the controller controls the dynamic indicators representing the lane markers M for the four lanes to increase in intensity. At this time, the overhead gantry sign **40** can display, for example, green arrows indicating that four lanes L**1** through L**4** are open. At the end of the road segment **18**, the dynamic indicators **16** end, and the road markers and shoulder lines are represented by conventional painted lines.

As can be appreciated from the above, the system **10** described herein saves significant costs when compared to construction costs for physically adding a lane to a road segment. The system **10** also avoids the costs and time required to acquire additional right-of-way and environmental impact studies associated with increasing the physical size of a roadway to add a lane. For instance, the system **10** can be implemented in months. The system **10** also avoids traffic disruptions commonly associated with physically widening a road, as well as changes in storm runoff, noise to surrounding areas and so on. Moreover, the decreased lane widths in the congested areas results in slower speeds which can increase driving safety.

In addition, the illuminated markers and lines as discussed above are more visible at night and during adverse weather conditions such as rainstorms, fog, ice and snow events. The system **10** can use white lighting in the dynamic indicators **16** for all interior lane markings, but utilize yellow in dynamic indicators **16** along perimeter conditions of lanes. Also, the overhead gantry signs **40** can display additional road information can be clearly and regularly provided to motorists. The gantry signs **40** can convey information on approaching backups, accidents, and other occurrences that impact the operations of the traditionally designed speed road. Additionally, the system **10** can control the dynamic indicators **16** to allows for the creation of a "fare" lanes (e.g., as designed by illumination color) to enable vehicles to travel in less congested lanes but pay for such usage.

GENERAL INTERPRETATION OF TERMS

In understanding the scope of the present invention, the term "comprising" and its derivatives, as used herein, are intended to be open ended terms that specify the presence of the stated features, elements, components, groups, integers, and/or steps, but do not exclude the presence of other unstated features, elements, components, groups, integers and/or steps. The foregoing also applies to words having similar meanings such as the terms, "including," "having" and their derivatives. Also, the terms "part," "section," "portion," "member" or "element" when used in the singular can have the dual meaning of a single part or a plurality of parts. The term "detect" as used herein to describe an operation or function carried out by a component, a section, a device or the like includes a component, a section, a device or the like that does not require physical detection, but rather includes determining, measuring, modeling, predicting or computing or the like to carry out the operation or function. The term "configured" as used herein to describe a component, section or part of a device includes hardware and/or software that is constructed and/or programmed to carry out the desired function.

While only selected embodiments have been chosen to illustrate the present invention, it will be apparent to those skilled in the art from this disclosure that various changes and modifications can be made herein without departing from the scope of the invention as defined in the appended claims. For example, the size, shape, location or orientation of the various components can be changed as needed and/or desired. Components that are shown directly connected or contacting each other can have intermediate structures disposed between them. The functions of one element can be performed by two, and vice versa. The structures and functions of one embodiment can be adopted in another embodiment. It is not necessary for all advantages to be present in a particular embodiment at the same time. Every feature which is unique from the prior art, alone or in combination with other features, also should be considered a separate description of further inventions by the applicant, including the structural and/or functional concepts embodied by such feature(s). Thus, the foregoing descriptions of the embodiments according to the present invention are provided for illustration only, and not for the purpose of limiting the invention as defined by the appended claims and their equivalents.

What is claimed is:

1. A system for dynamically modifying lane configurations on a road segment, comprising:

a plurality of dynamic lane markers disposed along the road segment that includes a beginning section, a

beginning transition section, a main section, an ending transition section, and an ending section, arranged in that order along a travel direction of the road segment, the dynamic lane markers being arranged as a plurality of first rows of the dynamic lane markers and a plurality of second rows of the dynamic lane markers in the beginning transition section, the main section and the ending transition section, each of the plurality of first rows of the dynamic lane markers extending in the travel direction of the road segment and being spaced sequentially apart from each other in a widthwise direction of the road segment to represent a first number of first lanes each having a respective lane width, each of the plurality of second rows of the dynamic lane markers extending in the travel direction of the road segment and being spaced sequentially apart from each other in the widthwise direction of the road segment to represent a second number of second lanes each having a respective lane width that is less than the respective lane width of a narrowest one of the first lanes, the second number of second lanes being greater than the first number of first lanes, and the first and second rows of the dynamic lane markers are alternately positioned in the widthwise direction of the road segment;

a plurality of shoulder lane markers disposed along the road segment, the shoulder lane markers being arranged as a first shoulder marker that separates a first shoulder of the road segment and a travel area of the road segment, and a second shoulder marker that separates a second shoulder of the road segment and the travel area of the road segment, with the first and second rows of the dynamic lane markers being between the first shoulder marker and the second shoulder marker, the first shoulder marker and the second shoulder marker are spaced from each other in the widthwise direction of the road segment to define a first travel area width at an initial portion of the beginning section and a second travel area width, greater than the first travel area width, at a remaining portion of the beginning section such that the second travel area width continues from the remaining portion of the beginning section, throughout the beginning transition section, the main section and the ending transition section and for at least a portion of the ending section adjacent to the ending transition section, and the first travel area width exists at an ending portion of the ending section;

a plurality of beginning transitional dynamic lane markers disposed along the beginning transition section and extending in the travel direction of the road segment to form a plurality of beginning transitional rows of the beginning transitional dynamic lane markers that extend transverse with respect to the travel direction of the road segment and transverse to the first and second lanes to represent a plurality of beginning transitional lanes each having a beginning transitional width that decreases along the direction of travel from a boundary of the beginning section and the beginning transition section to a boundary of the beginning transition section and the main section;

a plurality of ending transitional dynamic lane markers disposed along the ending transition section and extending in the travel direction of the road segment to form a plurality of ending transitional rows of the ending transitional dynamic lane markers that extend transverse with respect to the travel direction of the road segment and transverse to the first and second lanes to represent a plurality of ending transitional lanes each having an ending transitional width that increases along the direction of travel from a boundary of the main section and the ending transitional section to a boundary of the ending transition section and the ending section; and

a controller configured to determine whether a condition pertaining to the road segment exists, and in response to existence of the condition, control energization of the beginning transitional dynamic lane markers to define the beginning transitional lanes, control energization of the plurality of second rows of the dynamic lane markers to represent the second number of second lanes, and control energization of the ending transitional dynamic lane makers to define the ending transitional lanes;

the controller being further configured to, in response to the existence of the condition, control signs disposed along the road segment to provide traffic directing information relating to the beginning transitional lanes, the second number of second lanes and the ending transitional lanes; and

the controller being further configured to, in response to an absence of the condition, de-energize the beginning transitional dynamic lane markers, de-energize the plurality of second rows of the dynamic lane markers and control energization of the plurality of first rows of the dynamic lane markers to represent the first number of first lanes.

2. The system according to claim **1**, wherein

each of the dynamic lane markers includes an illumination device that emits light upon energization by the controller.

3. The system according to claim **1**, wherein

each of the dynamic lane markers includes a transmitter which, upon energization by the controller, emits signals for receipt by a vehicle to guide the vehicle along the road segment.

4. The system according to claim **1**, wherein

the condition represents a traffic condition relating to vehicle congestion in the road segment.

5. The system according to claim **1**, further comprising

a monitoring system configured to determine whether the condition pertaining to the road segment exists.

6. The system according to claim **1**, wherein

a ratio of the respective lane width of a narrowest one of the second lanes and the respective lane width of a narrowest one of the first lanes is 5:6.

7. The system according to claim **1**, wherein

each of the beginning transitional lanes begins at a respective one of the first rows of the dynamic lane markers and ends at a respective one of the second rows of the dynamic lane markers adjacent to the respective one of the first rows of the dynamic lane markers; and

each of the ending transitional lanes begins at a respective one of the second rows of the dynamic lane markers and ends at a respective one of the first rows of the dynamic lane markers adjacent to the respective one of the second rows of the dynamic lane markers.

8. The system according to claim **1**, wherein

the first shoulder marker and one of the first rows of the dynamic lane markers that is adjacent to the first shoulder marker defines an additional one of the first lanes when the one of the first rows of the dynamic lane markers are energized; and

the second shoulder marker and an other of the first rows of the dynamic lane markers that is adjacent to the second shoulder marker defines another additional one of the first lanes when the other one of the first rows of the dynamic lane markers are energized.

9. The system according to claim **8**, wherein

the first shoulder marker and one of the second rows of the dynamic lane markers that is adjacent to the first shoulder marker defines an additional one of the second lanes when the one of the second rows of the dynamic lane markers are energized; and

the second shoulder marker and an other of the second rows of the dynamic lane markers that is adjacent to the second shoulder marker defines another additional one of the second lanes when the other one of the second rows of the dynamic lane markers are energized.

10. The system according to claim **1**, wherein

each of the beginning transitional lanes begins at a respective one of the first rows of the dynamic lane markers and ends at a respective one of the second rows of the dynamic lane markers adjacent to the respective one of the first rows of the dynamic lane markers;

each of the ending transitional lanes begins at a respective one of the second rows of the dynamic lane markers and ends at a respective one of the first rows of the dynamic lane markers adjacent to the respective one of the second rows of the dynamic lane markers;

the first shoulder marker and one of the first rows of the dynamic lane markers that is adjacent to the first shoulder marker defines an additional one of the first lanes when the one of the first rows of the dynamic lane markers are energized;

the second shoulder marker and an other of the first rows of the dynamic lane markers that is adjacent to the second shoulder marker defines another additional one of the first lanes when the other one of the first rows of the dynamic lane markers are energized;

the first shoulder marker and one of the second rows of the dynamic lane markers that is adjacent to the first shoulder marker defines an additional one of the second lanes when the one of the second rows of the dynamic lane markers are energized; and

the second shoulder marker and an other of the second rows of the dynamic lane markers that is adjacent to the second shoulder marker defines another additional one of the second lanes when the other one of the second rows of the dynamic lane markers are energized.

11. The system according to claim **1**, wherein

the first shoulder marker includes a first shoulder row of shoulder dynamic lane markers, and the second shoulder marker includes a second shoulder row of the shoulder dynamic lane markers; and

the controller is further configured to control energization of the first and second shoulder rows of the shoulder dynamic lane markers to define the first and second travel area widths.

12. The system according to claim **11**, wherein

the first shoulder row of the shoulder dynamic lane markers and one of the first rows of the dynamic lane markers that is adjacent to the first shoulder row of the dynamic lane markers defines an additional one of the first lanes when the first shoulder row of the shoulder dynamic lane markers and the one of the first rows of the dynamic lane markers are energized; and

the second shoulder row of the shoulder dynamic lane markers and an other of the first rows of the dynamic lane markers that is adjacent to the second shoulder row of the shoulder dynamic lane markers defines another additional one of the first lanes when the second shoulder row of the shoulder dynamic lane markers and the other one of the first rows of the dynamic lane markers are energized.

13. The system according to claim **12**, wherein

the first shoulder row of the shoulder dynamic lane markers and one of the second rows of the dynamic lane markers that is adjacent to the first shoulder row of the shoulder dynamic lane markers defines an additional one of the second lanes when the first shoulder row of the shoulder dynamic lane markers and the one of the second rows of the dynamic lane markers are energized; and

the second shoulder row of the shoulder dynamic lane markers and an other of the second rows of the dynamic lane markers that is adjacent to the second shoulder row of the shoulder dynamic lane markers defines another additional one of the second lanes when the second shoulder row of the shoulder dynamic lane markers and the other one of the second rows of the dynamic lane markers are energized.

14. The system according to claim **1**, wherein

the respective lane width of a widest one of the first lanes is sufficient to accommodate an automobile, and the respective lane width of a narrowest one of the second lanes is sufficient to accommodate that same automobile.

* * * * *